

Reliability of tests to determine peak aerobic power, anaerobic power and isokinetic muscle strength in children with spastic cerebral palsy.

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RELIABILITY OF TESTS TO DETERMINE PEAK AEROBIC POWER, ANAEROBIC POWER AND ISOKINETIC MUSCLE STRENGTH IN CHILDREN WITH SPASTIC CEREBRAL PALSY

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Cerebral palsy (CP) is an inclusive term used to describe a number of chronic, non-progressive disorders of motor function that occur in young children as a result of disease of the brain (Ingram 1966). The most common form of CP is the spastic type, which accounts for approximately two-thirds to three-quarters of all children with CP (Gamstorp 1985). Proneness to fatigue and low muscle strength are characteristic symptoms in CP (Brown 1975).

Monitoring the physical capacity of children with CP is of dual importance. On the one hand, it can yield information on the functional severity and natural history of the disease; on the other, it can help assess the effects of therapeutic interventions such as diet, physical therapy, occupational therapy or conditioning (Bar-Or 1986).

In the present study, the reliability of tests to determine peak aerobic power, anaerobic power and isokinetic muscle strength was established in young children with spastic CP. In addition, results found in the children with CP were compared with measurements in healthy controls.

Subjects and method

SUBJECTS

The total study group consisted of 12 children with spastic CP (six boys and six

girls) and 39 healthy children (22 boys and 17 girls) between 6 and 12 years of age. The children with CP were classified according to the methods of Hagberg (Olow and Berg 1970) and Cruickshank (1966) by a physician at the Children's Rehabilitation Centre Franciscusoord in Valkenburg (Table I). Ten children with CP were classified as diplegic (legs and feet more affected than arms and hands); two were classified as tetraplegic (greater involvement of the upper part of the body than of the lower part). The children with CP were attending the elementary school at Franciscusoord (normal intelligence and mild mental retardation). The healthy children were recruited from an elementary school in Maastricht (normal intelligence). The children and their parents were informed of all aspects of the study and written consent was obtained. The study was approved by the Medical Ethical Committee of the University of Limburg and the Cooperating Rehabilitation Centres Limburg.

ANTHROPOMETRIC MEASUREMENTS

Body mass was obtained (Seca Germany) with the children wearing underclothing. For the children with CP a chair scale was used. Height measurements were taken while standing against a wall, or if unable to stand independently, while lying on a bed with a wooden T-square or a flexible

TABLE 1
Classification of the 12 children with CP

No.	Sex	CP classification*			Severity†	Mode of ambulation
		Tonus	Abnormal movements	Distribution		
1	M	Hyper	—	Diplegia	1	Ambulant
2	M	Hyper	—	Diplegia	1	Ambulant
3	F	Hyper	—	Diplegia	1	Ambulant
4	M	Hyper	—	Diplegia	2	Ambulant
5	F	Hyper	—	Diplegia	1	Ambulant
7	F	Hyper	Ataxia	Diplegia	2	Ambulant
8	M	Hyper	Ataxia	Diplegia	2	Ambulant
9	F	Hyper	—	Diplegia	2	Wheelchair
10	F	Hyper	—	Diplegia	2	Wheelchair
17	M	Hyper	—	Tetraplegia	3	Wheelchair
23	M	Hyper	—	Diplegia	2	Ambulant
28	F	Hyper	Ataxia/athetosis	Tetraplegia	3	Wheelchair

*According to the classification of Hagberg (Olow and Berg 1970).

†Gradation according to Cruickshank (1966): 1, may appear normal except that the precision of the movement may be impaired; 3, unable to care for all his bodily needs because he is unable to walk unassisted, talk clearly or has little use of his hands; 2, between 1 and 3.

tape. The thickness of four skinfolds (biceps, triceps, subscapular, supra-iliac) was measured with a Servier caliper on the non-dominant side of the body.

PEAK AEROBIC POWER

In the children with CP, four progressive maximal aerobic exercise tests (based on the McMaster All-Out Progressive Continuous Cycling Test) (Bar-Or 1983) were performed on a mechanically braked Monark leg cycle ergometer. The first test was a habituation test, which was also used to check the protocol and find out whether the children with CP needed fixations on the pedals. This habituation test was followed by three 'real' tests within a period of three weeks. The healthy children performed two progressive maximal aerobic exercise tests within a period of three weeks. Resistance was increased every 2 min with a variable load, depending on the abilities of the child, until the child was unable to continue pedalling. Individual protocols were constructed such that the total exercise time ranged between 8 min and 12 min. No fixed pedalling rate was required; the number of revolutions was recorded. All the tests were preceded by a warm-up of about 5 min and verbal encouragement was given throughout the tests. Peak aerobic power was defined as

the highest power output over the 2 min of a load. When the child could not complete 2 minutes of the final load, peak power was calculated as the mean of the power of the penultimate stage and the final stage. Peak heart rate (HR, measured with a Sport Tester PE3000, Polar Electro, Finland) was defined as the highest average HR over the last minute of a load.

ANAEROBIC POWER

Anaerobic performance was measured by the Wingate Anaerobic Cycling Test (WAnT). A detailed description of this test can be found elsewhere (Dotan and Bar-Or 1980, Bar-Or 1987). Briefly, the WAnT is a 30 s cycling test at all-out speed, against a constant braking force. The children with CP performed the WAnT four times on the mechanically braked Monark leg cycle ergometer. The first test was a practice session. By trial and error the force was determined that elicited the highest power (=optimal braking force). Subsequently, three tests were performed on each child with CP, within a period of three weeks, using this predetermined force setting. In the healthy children, two tests were performed during a time span of three weeks. All the tests were preceded by a warm-up of about 5 min and verbal

TABLE II
Classification of the 12 children with CP and the 39 healthy children

	<i>N</i>	<i>Age</i> (yrs)	<i>Height</i> (cm)	<i>Mass</i> (kg)	<i>Sum four</i> <i>skinfolds</i> (mm)	<i>BMI</i> ¹ (kg/m ²)
CP M	6	8.2 ± 1.5 (7-11)	128.8 ± 10.3 (121.0-151.0)	30.4 ± 12.5 (20.0-57.0)	30.0 ± 14.6 (14.0-58.0)	17.6 ± 3.8 (13.7-25.0)
CP F	6	9.3 ± 1.8 (7-12)	134.4 ± 12.7 (120.0-152.5)	35.1 ± 16.3 (19.0-68.0)	36.0 ± 17.5 (23.0-70.0)	18.5 ± 5.3 (13.2-29.2)
Healthy M	22	9.0 ± 2.2 (6-12)	138.0 ± 12.9 (116.5-160.0)	33.6 ± 9.1 (21.0-57.0)	22.5 ± 4.2 (15.0-32.0) *	17.3 ± 1.8 (14.8-22.3)
Healthy F	17	9.5 ± 1.9 (6-12)	141.3 ± 11.6 (124.5-166.5)	36.1 ± 7.7 (25.0-52.0)	31.2 ± 8.0 (16.0-44.0)	17.8 ± 1.5 (14.7-20.4)

Values are means ±SD, with ranges in parentheses.

¹BMI: body mass index; * $p < 0.001$.

encouragement was given throughout the 30s period. Pedal revolutions were registered continuously. Two performance indices were calculated: peak power (PP, reflecting the ability of the limb muscles to produce high mechanical power in a short time) and mean power (MP, reflecting the ability to sustain high power) (Bar-Or 1987).

ISOKINETIC MUSCLE STRENGTH

Muscle strength was determined by an isokinetic device (Cybex II, Ronkonkoma, NY, USA), recording strength as torque in Nm. Details concerning the principles of isokinetic exercise may be found elsewhere (Hislop and Perrine 1967, Thistle *et al.* 1967). Torque determinations were made on the extensor and flexor muscles of the knees at three different angle speeds (30°/s, 60°/s, 120°/s). The test was conducted while the child was seated in an erect position with thigh and pelvis stabilized. All measurements were performed at the damping levels recommended by the Cybex Testing Manual (1983). After two trial motions at each speed to familiarize the subject with the testing apparatus, each subject performed five maximal contractions, starting with the least affected/dominant leg (children with CP and healthy children, respectively) at the different speeds (test 1). Each subject started at an angular velocity of 30°/s and

had brief rest intervals between the different speeds. Verbal encouragement was given to exert maximal effort. After repositioning the apparatus, the subject completed the above procedures for the opposite limb. The reliability of the test (within-day reliability) was established by repeating the protocol after a rest period of about 1.5h (test 2). Peak torque (PT) was defined as the maximum torque generated by the subject throughout one series of repetitions.

The healthy children performed the aerobic and anaerobic cycle test on the same day (with a sufficient break between the two tests); cycle tests in the children with CP were on separate days. Isokinetic strength tests were in both groups of children on separate days. For practical reasons, the numbers of children differed between the three physical capacity tests.

STATISTICAL ANALYSIS

Data are presented as means ±SD. Comparisons between data were made with the Friedman test (k related samples) and the Wilcoxon test (two related samples) for paired observations and the MannWhitney U test for unpaired observations ($\alpha = 0.05$). Test-retest reliability was established by Spearman's rank order correlation (r_s). Because of different ranges in test outcome between the children with CP and the healthy

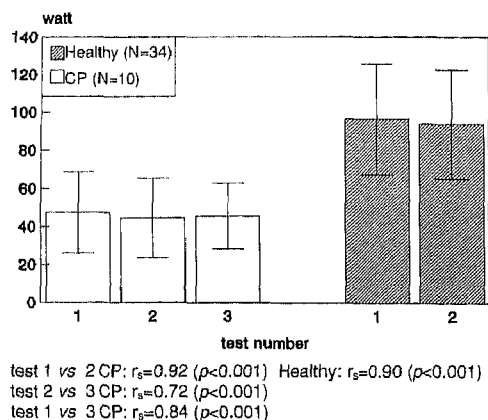


Fig. 1. Peak aerobic power (W) during different tests in 10 children with spastic CP and 34 healthy children.

children, the intra-individual difference between tests was calculated as a percentage of the mean individual test outcome.

Results

Characteristics of the children with CP and the healthy group are presented in Table II. None of the differences in characteristics between the children with CP and the healthy group was statistically significant. The healthy girls had a significantly higher ($p<0.001$) sum of four skinfolds than the healthy boys, whereas the difference between the boys with CP and girls with CP was not statistically significant.

PEAK AEROBIC POWER

Peak aerobic power in the children with CP (six boys, four girls; eight diplegic, two tetraplegic) and in the healthy children (22 boys and 12 girls) did not differ significantly between the tests (Fig. 1). Test-retest correlation coefficients for peak aerobic power between the first and second test were similar in the children with CP and healthy children. However, the intra-individual difference (as a percentage of the mean power; absolute intra-individual differences were similar in the two groups) between the first and second test was significantly higher ($p<0.05$) in the children with CP ($19.1 \pm 11.8\%$) than in the healthy children ($9.9 \pm 7.4\%$). Intra-individual differences between tests one and three and between

tests two and three in the group with CP, did not differ from the intra-individual difference between the first and second tests.

Spearman's correlation between body mass and peak aerobic power was 0.73 ($p<0.01$) in the group with CP and 0.83 ($p<0.001$) in the healthy group. Peak aerobic power (W/kg) was on average 46% lower ($p<0.001$) in the children with CP (1.5 ± 0.5 W/kg) than in the healthy children (2.8 ± 0.4 W/kg). In three children with CP (numbers 1, 2 and 4; Table I), peak aerobic power per kg was within the range found in their healthy peers.

Peak HR almost always occurred in the final load of a test. Peak HR in the children with CP was 168 ± 15 bpm in the first test, 167 ± 14 bpm in the second test and 164 ± 13 bpm in the third test. Differences in peak HR between the tests were not statistically significant. Peak HR in the children with CP was on average 13% lower ($p<0.001$) than in the healthy children. Peak HR in the healthy children did not differ between the two tests (191 ± 12 bpm in the first test and 190 ± 13 bpm in the second test).

ANAEROBIC POWER

PP in the children with CP (six boys, six girls; 10 diplegic, two tetraplegic) tended to increase from the first to the third test (Fig. 2). This increase of 14% was, however, not statistically significant ($p=0.08$). MP in the group with CP did not differ significantly between the tests. In the healthy children (22 boys and 12 girls), there were no statistically significant differences in PP and MP between the two tests (Fig. 3). Test-retest correlation coefficients for PP and MP were similar in both groups of children (Figs. 2, 3). Mean intra-individual differences in PP and MP (as a percentage of the mean power; absolute intra-individual differences tended to be higher (ns) in the healthy group) between the first and second test were $14.2 \pm 13.4\%$ (CP) and $6.8 \pm 8.0\%$ (healthy) for PP and $12.3 \pm 12.1\%$ (CP) and $9.7 \pm 7.2\%$ (healthy) for MP (ns). Intra-individual differences between tests one and three and between tests two and three in the group with CP did not differ from the intra-individual differences between the first and second tests.

Spearman's correlations between body mass and anaerobic performance were 0.73 ($p < 0.001$) in the children with CP and 0.79 ($p < 0.001$) in the healthy children. PP (W/kg) was on average 55% lower ($p < 0.001$) in the children with CP (3.0 ± 1.3 W/kg) than in the healthy children (6.6 ± 1.0 W/kg). MP (W/kg) was on average 50% lower ($p < 0.001$) in the children with CP (2.3 ± 0.9 W/kg) than in the healthy children (4.6 ± 0.7 W/kg). Anaerobic performance was in only two children with CP (numbers 1 and 4; Table I) within the range found in their healthy peers.

ISOKINETIC MUSCLE STRENGTH

In Table III, flexion and extension PT (Nm), test-retest correlation coefficients and intra-individual differences (as a percentage of mean PT), are presented for the different speeds during the two tests. The isokinetic strength test could not be performed in four children of the group with CP because muscle strength was too weak. In the children with CP (five boys, three girls; all diplegic), there were no significant differences in flexion and extension PT between the two tests. In the healthy children (21 boys, 17 girls), flexion and extension PT at 30°/s and flexion PT at 60°/s were in the second test lower (on average 4%, $p < 0.05$) than in the first test. Test-retest correlation coefficients were at all speeds lower in the group with CP than in the healthy group. Intra-individual differences (as a percentage of the mean PT; absolute intra-individual differences were similar in both groups) were significantly higher ($p < 0.01$) in the group with CP than in the healthy group at 60°/s (flexion) and at 120°/s (flexion and extension).

At 30°/s and 60°/s, PT in the group with CP was on average 25% ($p < 0.05$) higher in the less affected leg than in the more affected leg. At 120°/s there was no significant difference between legs. In the healthy children, comparisons between dominant and non-dominant leg yielded no consistent results.

Because higher correlations were found between height and PT (CP: mean r_s over the different speeds = 0.53 ± 0.06 ; healthy: mean r_s = 0.89 ± 0.03) than between weight and PT (CP: mean r_s =

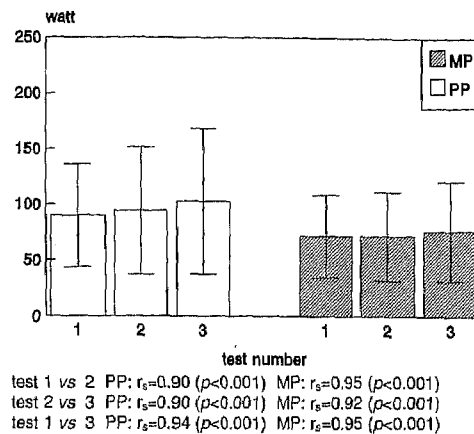


Fig. 2. Peak anaerobic power (PP; W) and mean anaerobic power (MP; W) during three tests in 12 children with spastic CP.

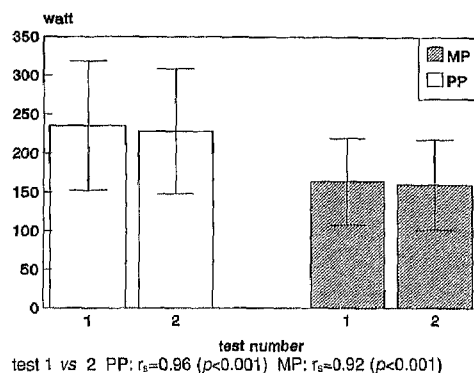


Fig. 3. Peak anaerobic power (PP; W) and mean anaerobic power (MP; W) during two tests in 34 healthy children.

0.46 ± 0.07 ; healthy: mean r_s = 0.83 ± 0.03), PT data between the children with CP and the healthy group were compared when expressed per cm body height. Flexion and extension PT/cm were on average (over the three test velocities) 53% and 48% ($p < 0.001$) lower in the children with CP than in the healthy children respectively. Only two children with CP (numbers 2 and 4; Table I), had PT values within the range of their healthy peers.

Discussion

In comparison with representative samples of the Dutch population of the same age (Roede and van Wieringen 1985), the

TABLE III
Mean scores (SD) of knee flexion and extension peak torque, test-retest correlation coefficients (r_s) and intra-individual difference during two tests in eight children with CP and 38 healthy children

	Speed (°/s)	Flexion Test 1 (N m)	Test 2 (N m)	r_s	ID ¹ (%)	Extension Test 1 (N m)	Test 2 (N m)	r_s	ID (%)
CP	30	23.7 (9.1)	21.9 (10.0)	0.84*	25.1 (26.7)	41.3 (15.7)	39.5 (16.7)	0.71**	25.3 (25.3)
	60	21.2 (10.1)	20.2 (8.8)	0.75*	29.9 (20.0)	39.4 (19.5)	39.8 (17.4)	0.55	29.6 (24.9)
	120	18.3 (8.2)	19.0 (7.8)	0.65**	32.1 (27.4)	27.1 (9.7)	30.8 (12.8)	0.42	33.8 (27.6)
Healthy	30	49.6 (20.5)	47.1 (19.1)	0.88*	14.7 (13.9)	75.4 (32.7)	72.2 (32.7)	0.95*	11.6 (9.2)
	60	47.1 (19.2)	45.3 (19.2)	0.90*	12.5 (11.5)	73.6 (29.2)	70.9 (31.9)	0.90*	17.1 (14.2)
	120	44.4 (19.3)	43.3 (18.7)	0.91*	15.9 (14.9)	59.8 (24.6)	58.2 (24.0)	0.92*	12.7 (12.7)

¹ ID = intra-individual difference, * $p < 0.001$, ** $p < 0.05$, *** $p < 0.05$. N=7.

For flexion at 60°/s and 120°/s, and extension at 120°/s: ID is significantly different ($p < 0.01$) between the group with CP and the healthy group.

healthy children were on average heavy for their height (boys on average 3 kg heavier than the mean weight for height; girls 4 kg heavier). The healthy girls were also tall for their age (on average 3 cm taller than standards of attained height in Dutch children). The children with CP were, in comparison with the Dutch reference data (Roede and van Wieringen 1985), small for their age (boys on average 2 cm shorter than reference data; girls on average 4 cm shorter) and heavy for their height (boys on average 5 kg heavier, girls 7 kg heavier than the mean weight for height of Dutch children). The short stature of the children with CP is in conformity with previously published reports (Tobis *et al.* 1961, Ruby and Matheny 1962). The large weight for height in the children with CP was also found in the study of Berg and Isaksson (1970) in severely handicapped children with CP.

PEAK AEROBIC POWER

The results obtained during the different tests suggest that, both in the children with CP and in the healthy group, the

peak aerobic power tests are reliable. Absolute values of peak aerobic power of the healthy children of the present study are in agreement with cycle ergometry studies as presented by Bar-Or (1983) and Washington *et al.* (1988). When expressed per kg body mass, the peak aerobic power of the healthy children of the present study was about 20% lower, but this was probably due to the relatively high body mass in the present study. The children with CP had on average only about 50% of the aerobic power (in absolute terms and per kg body mass) of the healthy children. This subnormal aerobic power in CP is in agreement with previous reports (Lundberg 1978, 1984; Dresen *et al.* 1982; Bar-Or 1983, 1986).

The significantly lower peak HR in the children with CP than in the healthy children suggests that peak aerobic performance during leg cycling was attained at a lower level of cardiorespiratory stress in the group with CP than in the healthy group. Apparently, aerobic exercise testing by means of cycle ergometry in these children is restricted by non-cardiorespiratory factors.

ANAEROBIC POWER

PP (in absolute units) in the healthy children was in good agreement with studies in healthy children in Canada and Israel (Bar-Or 1983). MP was, in comparison with those studies, on average about 15 to 20% lower (particularly in the boys). When expressed per kg body mass, PP and MP were about 8% and 23% lower, respectively, than the data of Bar-Or (1983), but this can partly be explained by the relatively high body mass in the present study. Anaerobic performance in the children with CP was distinctly subnormal when compared with the healthy children, which is in agreement with the study of Parker *et al.* (1992).

The high test-retest correlation coefficients found in the present study indicate that the WAnT is highly reliable in groups of young children with CP and young healthy children. This is in agreement with studies in healthy subjects, patients with chronic obstructive lung disease and patients with neuromuscular disease, including children with spastic CP (Bar-Or 1987, Tirosch *et al.* 1990). PP showed a tendency to increase with repeated testing in the children with CP, an effect that was not seen in the healthy group. Although the increase did not reach statistical significance ($p = 0.08$), the possibility of a gradual increase in PP with repeated testing over a short time cannot be excluded.

ISOKINETIC MUSCLE STRENGTH

PT measurements at 30°/s in the healthy children of the present study showed good agreement with previously reported results in healthy children of the same age in the USA (Gilliam *et al.* 1979). Results at 120°/s were about 10 to 15% higher in the present study. To our knowledge there is no literature available on PT of the knee flexors and extensors at 60°/s in healthy children, nor on PT measurements in young children with spastic CP. Similar to the results we found on aerobic and anaerobic power, PT in the children with CP is extremely low when compared with their healthy peers.

From studies of Alexander and Molnar (1973) and Molnar *et al.* (1979), it can be concluded that, in young children (7 to 15 years) with normal intelligence and mild

mental retardation, isokinetic muscle strength testing is a reliable and reproducible technique. The results from the healthy children in the present study confirm this high reliability of isokinetic strength testing. However, the data from our study cannot quite be compared with the studies of Alexander and Molnar, because they established the test-retest reliability on different days, whereas in the present study the within-day reliability was assessed.

In the children with CP, extension PT cannot be measured reliably at higher test velocities (60°/s and 120°/s). A possible explanation for this could be that the coordination of agonist and antagonist muscles is more impaired at higher velocities than at lower velocities (this could also explain the lack of difference in PT between less affected and more affected leg at 120°/s). However, when the test velocity of 30°/s is used, isokinetic strength testing seems to provide an objective, safe (muscles cannot be overloaded) and reliable method to determine the torque-generating capabilities in groups of young children with spastic CP.

Conclusion

The results of the present study indicate that, as in healthy children, peak aerobic power, anaerobic power, and isokinetic muscle strength (at 30°/s), can be measured reliably in groups of young children with spastic CP. The higher intra-individual differences in the group with CP than in the healthy group suggest that, at an individual level, the tests are less suitable for children with CP than in their healthy peers (possibly because of attention deficits, which are known to occur in CP (Binder and Eng 1989)). These findings have important implications for the use of the described physical capacity tests in children with CP. The tests are valuable for rehabilitation research in groups of children with CP (for example, evaluation of sports or physical therapy programmes). In clinical settings, however, one should be careful when interpreting the test results.

It is evident that the measured variables are distinctly subnormal in most of the children with CP when compared with their healthy peers. Only three children

with CP had test outcomes within the normal range. Possible explanations for this could be agonist/antagonist co-contraction, low muscle mass (especially of the fast-twitch fibres), the presence of contractures, detraining, and attention deficits.

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Authors' Appointments

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SUMMARY

Test-retest reliability of measurements of peak aerobic power (cycle ergometer), anaerobic power (cycle ergometer), and isokinetic muscle strength of the knee (Cybex) was established in 12 young children with cerebral palsy (spastic diplegia/tetraplegia; mean age 8.8 years) and in addition in 39 healthy controls (mean age 9.2 years). The cycle ergometer tests were found to be reliable in both the group with CP and the control group (test-retest correlations varying from 0.72 to 0.96). The isokinetic strength test in the group with CP was only reliable at 30°/s, whereas in the control group high test-retest correlations were also found at 60°/s and 120°/s.

RÉSUMÉ

Fidélité des tests de détermination de la puissance de pointe en aérobie et anaérobie, et de la force musculaire isocinétique chez les enfants IMC et les contrôles en bonne santé

La fidélité test-retest des mesures de puissance de pointe en aérobie (cycle ergométrique) et en anaérobie (cycle ergométrique), et la force musculaire isocinétique du genou (Cybex) chez 12 jeunes IMC à forme spastique, diploégique/tétraploégique (moyenne d'âge 8.8 ans) et chez 39 contrôles en bonne santé (moyenne d'âge 9.2 ans) Les tests d'ergométrie sur cycles se montrèrent fiables tant dans le groupe IMC que le groupe contrôle (corrélations test-retest variant entre 0.72 et 0.96). Le test de force isocinétique dans le groupe IMC ne fut fidèle qu'à 30°/s, tandis que dans le groupe contrôle des corrélations test-retest élevées, à 60°/s et 120°/s étaient trouvées.

ZUSAMMENFASSUNG

Verlässlichkeit von Tests zur Bestimmung von Peak Aerobic Power, Anaerobic Power und isokinetischer Muskelkraft im Knie bei Kindern mit Cerebralparese und gesunden Kontrollen

Bei 12 Kindern mit Cerebralparese und spastischer Diplegie/Tetraplegie (mittleres Alter 8.8 Jahre) und bei 39 gesunden Kontrollen (mittleres Alter 9.2 Jahre) wurde die Test-retest Reliabilität von Messungen der Peak Aerobic Power (Fahrradergometer), der Anaerobic Power (Fahrradergometer) und der isokinetischen Muskelkraft im Knie (Cybex) untersucht. Die Fahrradergometer Tests erwiesen sich sowohl in der Gruppe mit Cerebralparese als auch in der Kontrollgruppe als verlässlich (Test-retest Korrelationen zwischen 0.72 und 0.96). Der isokinetische Krafttest war in der Gruppe mit Cerebralparese nur bei 30°/s verlässlich, während in der Kontrollgruppe hohe Test-retest Korrelationen bei 60°/s und 120°/s gefunden wurden.

RESUMEN

Fiabilidad de las pruebas para determinar el máximo de potencia aeróbica, anaeróbica y potencia muscular isoquinética, en niños con Parálisis Cerebral y en controles normales

Se establecieron pruebas y contrapruebas de fiabilidad de las mediciones del pico de potencia aeróbica (bicicleta ergométrica), anaeróbica (bicicleta ergométrica) y potencia muscular isoquinética de la rodilla (Cybex) en 12 niños con parálisis cerebral y diplegia-tetraplegia espástica (promedio de edad 8.8 años) y además en 39 controles sanos (edad promedio de 9.2 años). Se halló que la bicicleta ergométrica constituía la prueba más fiable en el grupo con PC y en el control (las correlaciones prueba-contraprueba variaban de 0.72 a 0.96). La prueba de fuerza isoquinética en el grupo con PC constituía la prueba fiable solamente en 30°/s, pero en el grupo control las correlaciones altas entre prueba y contraprueba se hallaron en 60°/s y 120°/s.

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